Records of Scattering Layers from New Zealand Seas

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HITHERTO THE SCATTERING of the ultrasonic pulses of echo sounding equipment attributable to biological agency (Johnson, 1948; Kampa and Boden, 1954*b*) has not been recorded from New Zealand waters. However, Dietz (1948) reported on occurrences, over extensive areas, of the deep scattering layer in the Pacific and Antarctic oceans, and on this ground alone, the presence of scattering in New Zealand waters could be expected. Recent investigations of occurrences and distribution of plankton in New Zealand waters (Bary, in press) suggest an abundant zooplankton, and it would appear also that suitable hydrological conditions for the necessary concentrations of organisms may exist in the disturbed, mixed waters which occur within the New Zealand area. Again, large shoals of pelagic fish are frequently seen in the coastal waters. It is therefore consistent that records are available which show scattering of sound from both plankton and fish.

The notes which follow deal briefly with some of these records from New Zealand. Both deep and shallow scattering layers, multiple layering, and scattering from fish shoals are discussed. One record is believed to show scattering from layers of zooplankton which are associated with a shoal of fish. Other records illustrate two related phenomena, that of separated multiple layers maintaining their identities throughout the ascent to the surface at night, and the converse—the differentiation and subsequent descent of separate layers from the surface at dawn.

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MATERIALS

The hydrographic survey being carried out by H.M.N.Z.S. "Lachlan" is a continuing source of fathograms of coastal and offshore waters. Other naval vessels and coastal and overseas merchant shipping have contributed many records from the high seas. "Lachlan" fathograms are particularly useful for shallow scattering records. The other shipping offers a source for deep scattering records, but in fact, no scattering has been detected in any of the fathograms from these ships. Some of the most useful records have originated in special investigations made in New Zealand waters by R.R.S. "Discovery II," of the National Institute of Oceanography, England, and by the Danish Expedition in H.D.M.S. "Galathea." I am most grateful for permission to reproduce records from both of these sources.

All examples of scattering have been obtained incidental to other requirements. For this reason the records are not always as clear as they might have been had the sounder been tuned to give maximum strength from the scattering layers. It is unfortunate, too, that promising records have been phased out in a number of instances; and additional difficulties are met in the fading of some fathograms made on iodide paper.

SCATTERING LAYER RECORDS

The localities and lineal extent of the records of scattering for the New Zealand area are shown in Figure 1. Figures 2 to 9 reproduce some examples, and a general summary of all occurrences is given in Table 1.

The ascents of the two shallow scattering layers are shown in Figure 2, a trace made

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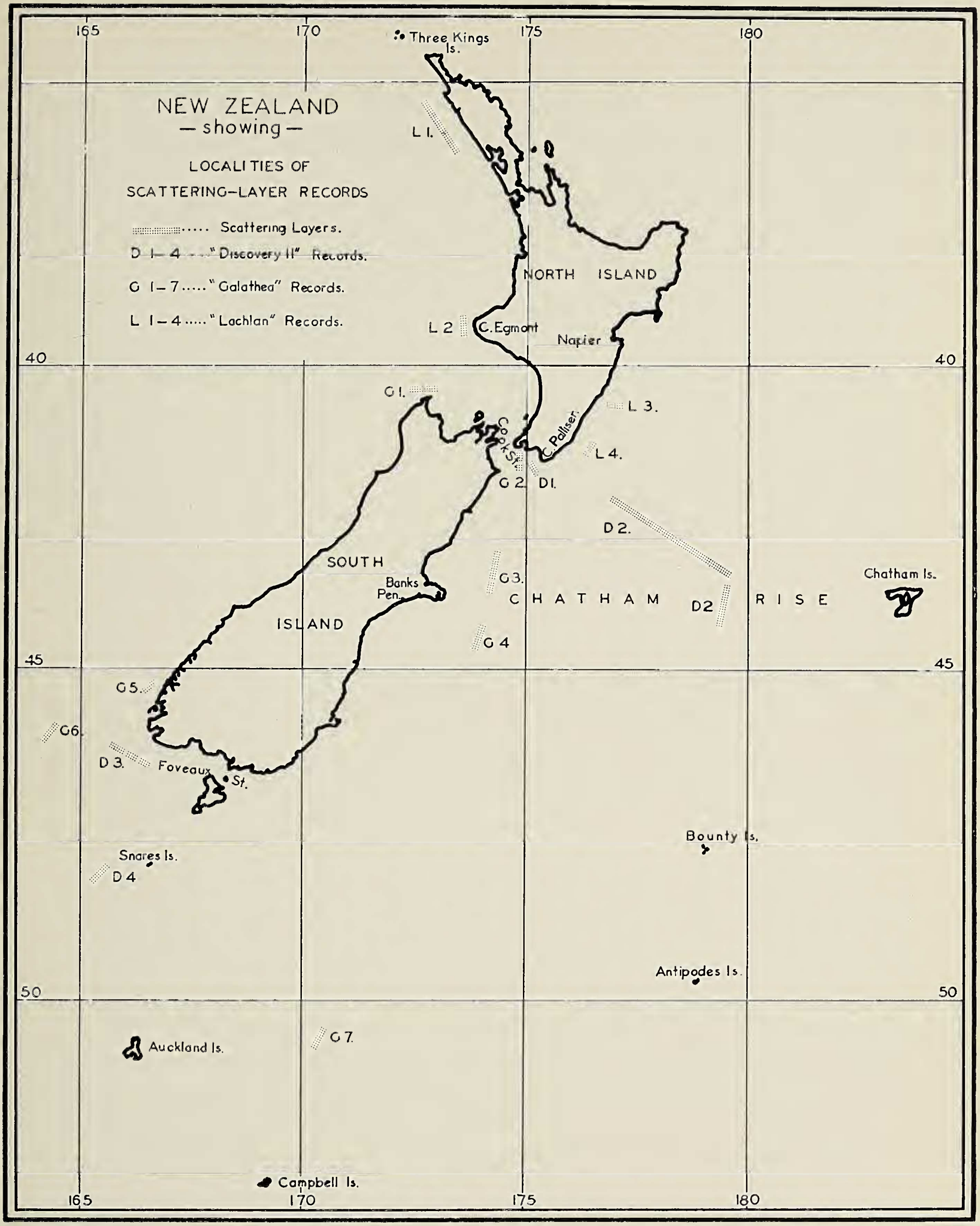


FIG. 1. The localities and approximate lineal extent of scattering layer records from New Zealand waters. All available records are shown (and see Table 1), but not all are otherwise referred to in the text.

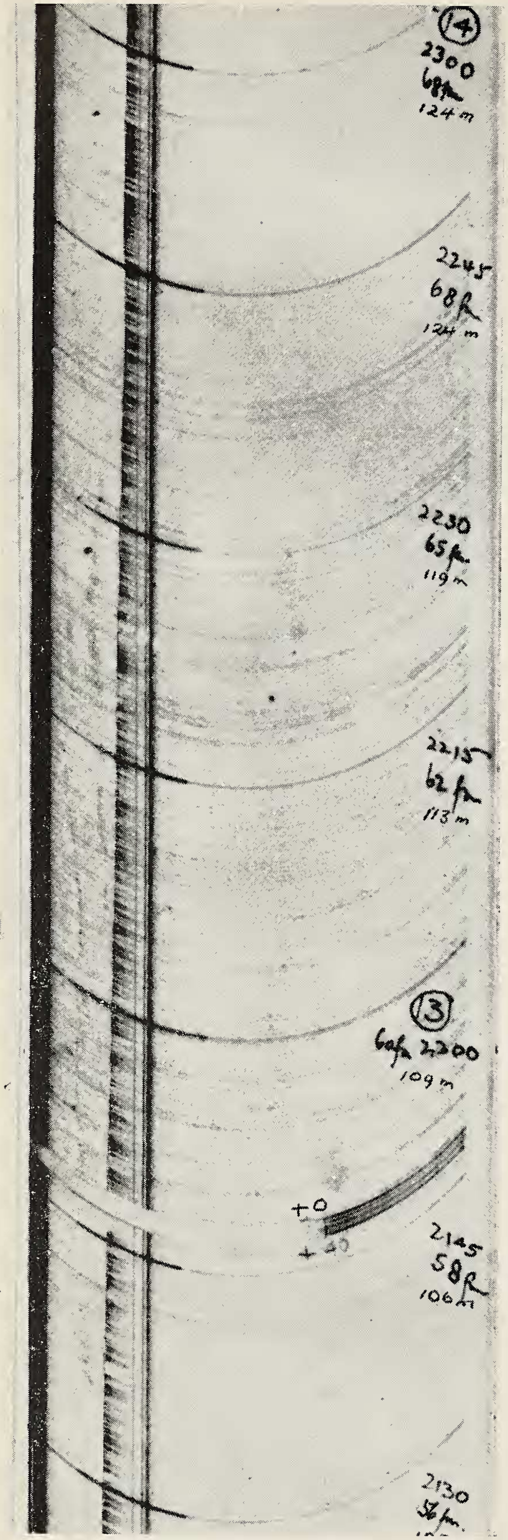
from "Lachlan" in coastal waters, eastern North Island (L2, in Fig. 1). This is not a strong record, but two separate layers, each of which is broken into parts, are visible ascending between the bottom and the surface. Rate of ascent for both layers is at ap-

TABLE 1
SOME FEATURES OF THE SCATTERING RECORDS FROM NEW ZEALAND SEAS

RECORD NO.	FIG. NO.	SHIP	DATE	TIMES	DEPTH OF WATER, (M.)	NOTES ON LAYER(S)	DEPTH OF SCATTERING, (M.)	RATE OF MOVEMENT, M./MIN.	POSSIBLE NATURE OF ORGANISMS
I.1	..	H.M.N.Z.S. "Lachlan"	11.V.54	2330–2345	530–402	Brief appearance of a single layer in ascent	73	..	Plankton and possibly fish
I.1	..	"	12.V.54	0130–0230	349–256	Double layer, clear of bottom and stationary	Between 109 and 183	..	
L2	2	"	10–11.V.54	2130–2300	110±	Two widely separated layers ascending between bottom and surface	91–0	1.5	Plankton
L2	3	"	11.V.54	0645–0800	119–137	Single layer in dawn descent	0–122	2.1 m./min. and 1.3 m./min.	Plankton
L3	7	"	12.II.54	2135–2235	Approx. 1828	Some multiple layering. Layers descending then ascending in an anomalous manner	91±	..	Plankton
L4	4	"	23–24.II.54	0430–0500	128–343	Separated, multiple layers, 15 mins. apart, in descent	0–64 0–35	Approx. 2	Plankton and fish shoal?
G1	..	H.D.M.S. "Galathea"	21.XII.51	0645–0745	110–70	Stationary layers and shoals	Between 50 and 70	..	Plankton and fish
G2	..	"	27.XII.51	2000–2230	90–600	Layering and shoals, stationary and in ascent	30 m. and 70–200	..	Mixed fish and plankton?
G3	5	"	27.XII.51	0400–0515	960–530	Separated multiple layers in descent	0–200	1.3 and 0.6	Plankton
G3	..	"	27.XII.51	0610–0700	570–380	Uneven shoals, lying parallel with the bottom	From 300–200	..	Fish?

TABLE 1—*Continued*
SOME FEATURES OF THE SCATTERING RECORDS FROM NEW ZEALAND SEAS

RECORD NO.	FIG. NO.	SHIP	DATE	TIMES	DEPTH OF WATER, (M.)	NOTES ON LAYER(S)	DEPTH OF SCATTERING, (M.)	RATE OF MOVEMENT, M./MIN.	POSSIBLE NATURE OF ORGANISMS
G4	6	H.D.M.S. "Galathea"	28.XII.51	1100–1244	330–540	Single layer at daylight level	Between 280 and 140	..	Plankton
G5	..	"	13.I.52	1900–2022	4300±	Deep, patchy layer, ascending and descending irregularly	Between 300 and 3000	..	Fish, or sounder fault?
G6	..	"	13.I.52	0915+	200	Short, dense layer lying near to and parallel with the bottom	200+	..	Probably fish
G7	..	"	29–30.XII.51	2400–0100	520	Faint scattering in mid-depths	Between 100 and 200	..	?
D1	..	R.R.S. "Discovery II"	2.XI.50	1630–1715	640–128	Faint to strong scattering at day level. Layer intercepts slope of shelf	238–183	..	Possibly plankton
D2	..	"	3–4.XI.50	0245–0830	519–366	Scattering in the surface waters, during descent, and at daylight level of 183 to 238 m.	Between 0 and 183–238	2.6	Plankton
D2	..	"	4–5.XI.50	0930–1207	311	Scattering stationary at daylight level	183	..	Plankton
D3	8 and 9	"	26.V.51	1650–1720 1845–55 1900–2130	128–338	Mixed shoals and layering. Scattering layers ascending, 2.0 m./min.	186–109	2.0	Plankton and fish
D4	..	"	11.XII.50	1656–1740	354–429	Faint scattering, parallel to, and near, deepening bottom	320–356	..	Fish?



proximately 1.5 m. per minute. The first begins to ascend at about 2130 hours, arriving at the surface around 2240; the second layer begins 15 min. later than the first and arrives at the surface at 2300 hours. Depth of water is between 102 and 124 m. The nighttime concentration of organisms at the surface is masked by the transmission signal. However, marked concentration in depth becomes apparent in the 15 to 20 minutes preceding the dawn descent (Fig. 3. This record is part of that shown in Fig. 2). This single layer begins to descend at 0645 hours. Downward migration is approximately 2.1 m. per min. during the first 30 minutes, but over the next 45 minutes the rate is slower, at approximately 1.3 m. per min. The layer retains its entity for a short while after it has reached the bottom.

Early stages in the descents of two separate layers are illustrated in Figure 4, a "Lachlan" trace from north of Cape Palliser (L4, in Fig. 1). The first layer descends clear of the transmission signal at approximately 0430 hours and after a short descent appears to split into two layers. One of these two appears to join with a second, dense layer which begins to descend about 15 minutes later than the first. Rate of descent is at about 2 m. per min. In a "Galathea" record made over the Chatham Rise and shown in Figure 5 (G3, in Fig. 1), two separate layers, preceded by a dense surface concentration, are shown during the dawn descent. The downward migration commences about 0400 hours and is strongly in evidence by 0500 hours. Both layers appear to split into two. Rates of descent approximate 1.3 and 0.6 m. per min. respectively for the first and second layers. The record rather abruptly fades out at 0515 hours.

A second "Galathea" record, Figure 6, shows a scattering layer at its daytime level. At its deepest the layer is at about 183 m., but its depth varies considerably. This record was made between 1100 and 1230 hours in

FIG. 2. The evening ascent of two separate layers in shallow coastal waters—the southern end of "Lachlan" record, L2, in Figure 1.

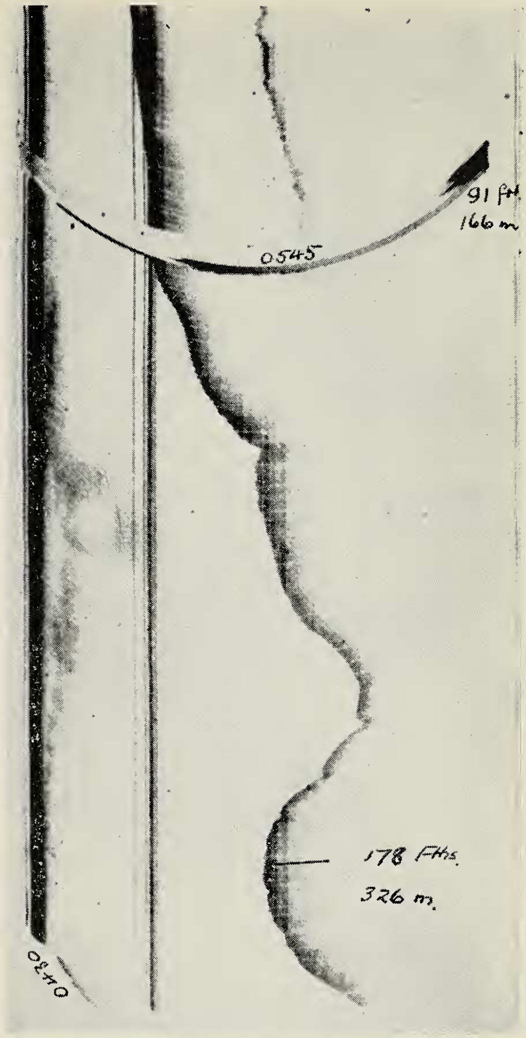


FIG. 4. The dawn descent of two separate layers, the first of which also splits into two; "Lachlan" record, L3.

water of 330 to 550 m. seaward of Banks Peninsula (G4 in Fig. 1).

Examples of more or less anomalous behaviour of layers are shown in Figures 7 and 8. Figure 7 is from a "Lachlan" fathogram made south of Napier (L3, in Fig. 1). It illustrates a scattering layer which is descending to a deeper level between 2135 and 2155 hours at which depth it becomes stationary

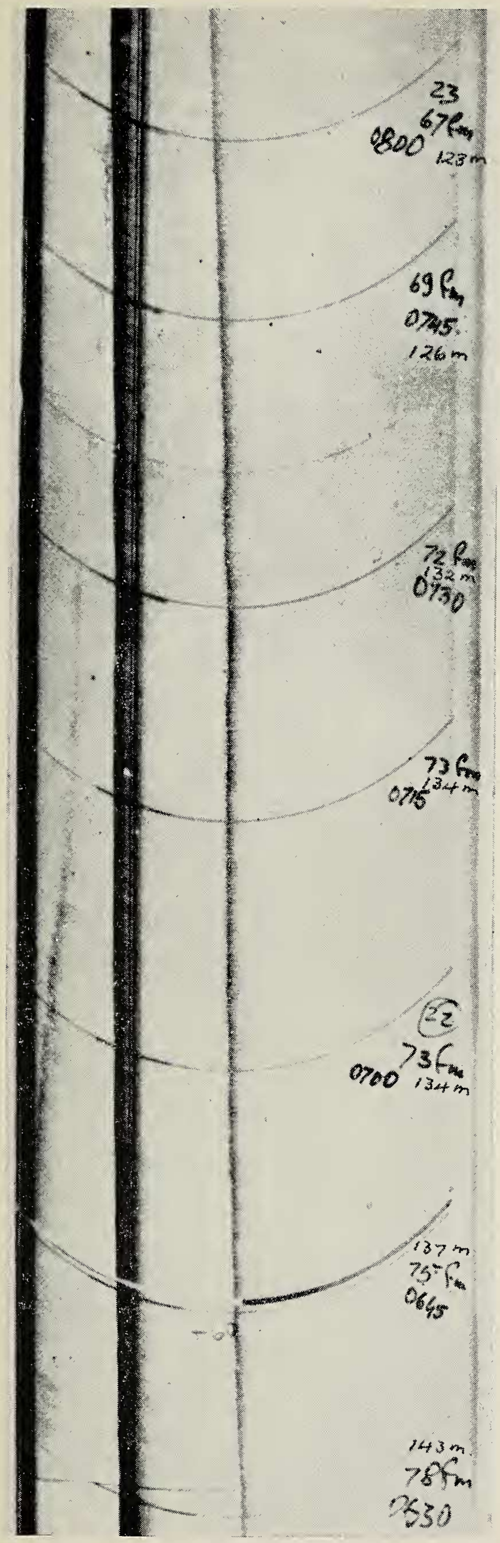


FIG. 3. The dawn descent. Note the concentration of organisms in depth prior to the differentiation and descent of the layer; the northern end of "Lachlan" record, L2.

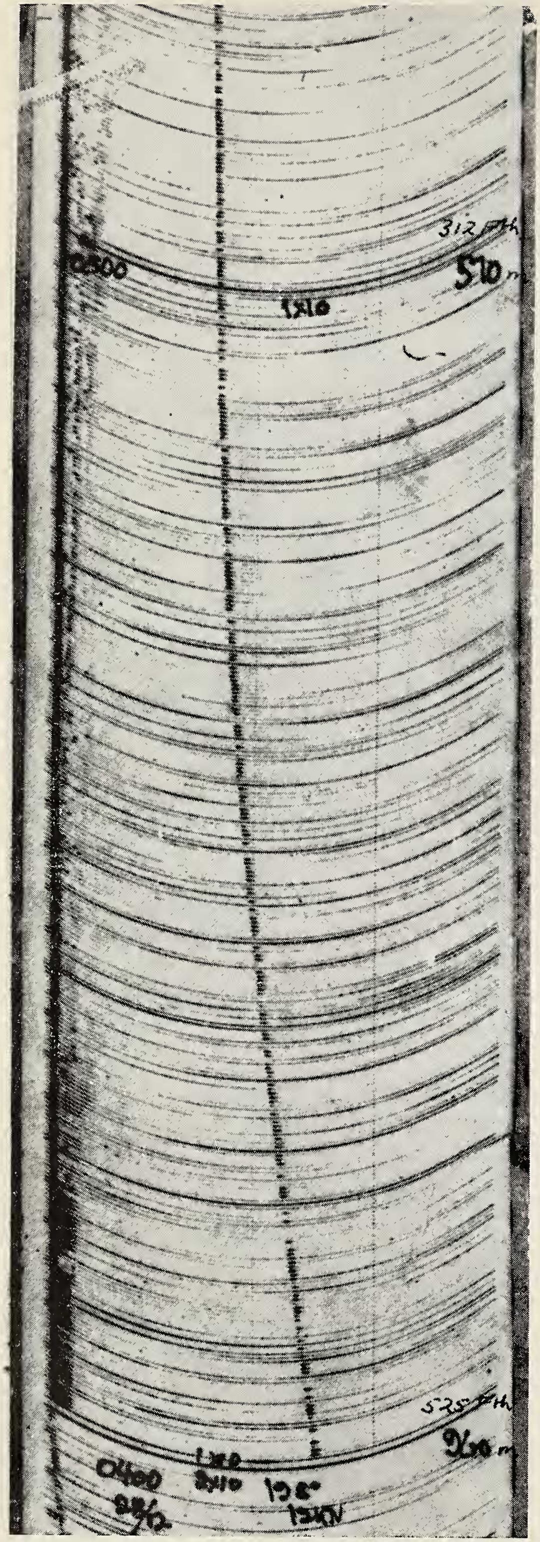


FIG. 5. The dawn descents of separated layers followed by splitting of each of the layers. The heavier trace in the second layer is suggestive of larger animals being present; "Galathea" record, G3.

for 15 minutes (around 2200 hours), and then rises slowly. Sunset was at 1930 hours (mid-February, 1954) and darkness would have fallen about an hour before this trace was commenced. The trace is of even texture with a suggestion of subsidiary layers within the main one; it is probably the result of scattering from zooplankton. If so, the record illustrates a curious reversal in the expected direction of movement of the organisms. It is possible that this special reaction is an effect of moonlight. The moon was in the first quarter and crossed the meridian at about 2130 hours on the day in question.

A "Discovery II" record (Fig. 8) made when approaching Foveaux Strait from the west (D3, in Fig. 1) is of strongly developed scattering most of which is remaining at depth. Sunset was at 1700 hours (May 1951), there was no moon, and it would have been dark for some time before 1950 hours when the record begins. The unevenly distributed, dense patches in this trace suggest that fish may have been the chief cause of the scattering. Fish do not necessarily perform diurnal migrations, and thus the fact that the main body of the scattering organisms is not ascending might be explained. On the other hand, three or four distinct layers can be detected in the earlier (left-hand) one-fifth of the record. These penetrate the fish scattering and are ascending towards the surface at rates of 2.0 to 2.5 m. per min. Their appearance is suggestive of scattering from planktonic organisms. This record may be indicative therefore of fish following and feeding on concentrations of plankton which are undergoing normal vertical migration.

Some other records are available, believed to be of scattering from fish shoals. Figure 9 illustrates one such record, made in the western approaches to Foveaux Strait by "Discovery II," earlier on the same day as that

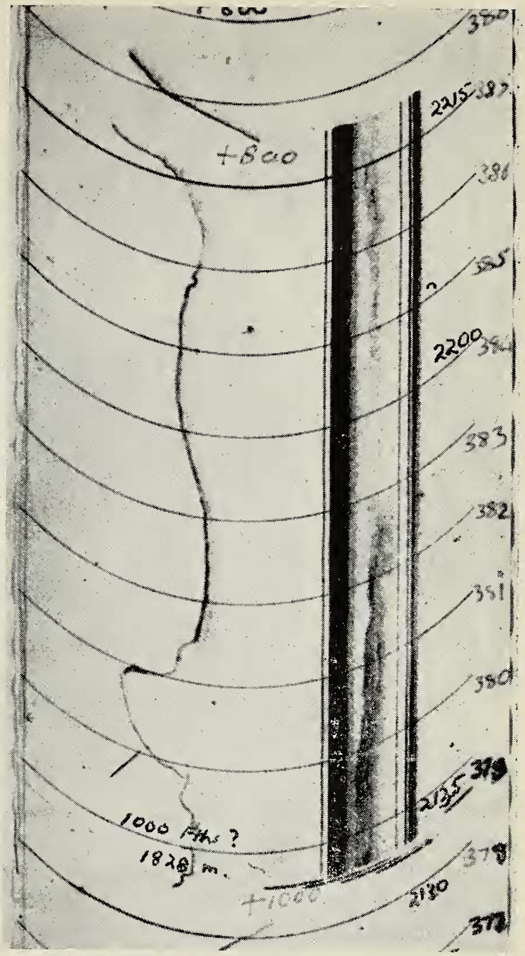


FIG. 7. Anomalous behaviour of a scattering layer during darkness. At first it is descending deeper into the water, and then begins to rise again. The phasing of the sounder has displaced the transmission signal down the fathogram; "Lachlan" record, L3.

shown in Figure 8. The dense shoal (marked "Fish?") would appear from its uneven denseness and patchiness, to be a large fish shoal, which then extends at lesser concentrations more or less parallel to the bottom. In view of the subsequent history of this zone of scattering—the record is continuous with that in Figure 8—it is possible that other pelagic organisms are contributing to it as well.

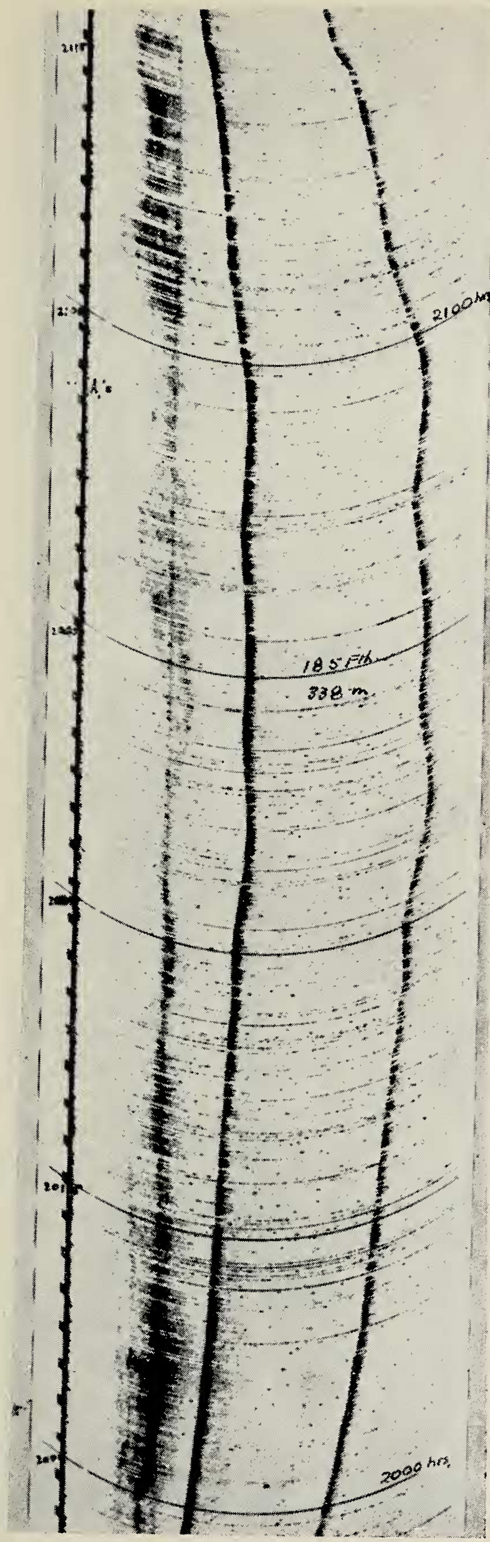


FIG. 6. A scattering layer maintaining a fluctuating daylight level in moderately deep water over the Chatham Rise; "Galathea" record, G4.

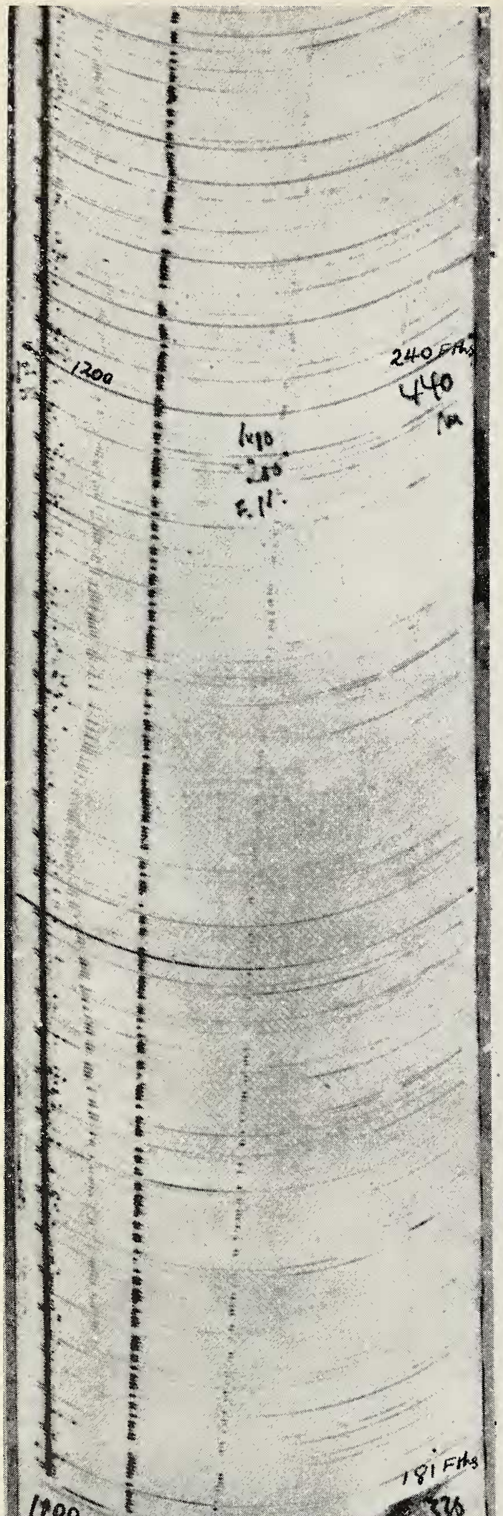
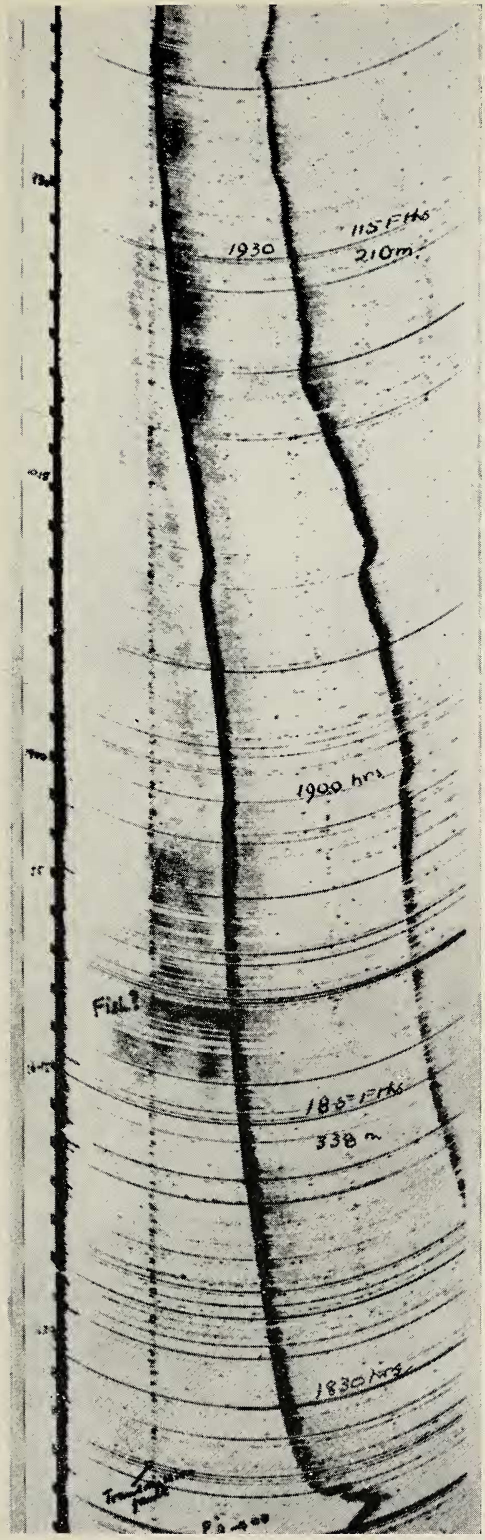


FIG. 8. Probable fish records combined with layers of plankton (on the left of the record). The latter are visible as three or four ascending layers cutting through the dense fish record; "Discovery II" record, D3.

DISCUSSION

Investigations of sound scattering of biological origin are being pursued for their bearing on studies of animal behaviour, distribution and ecology (Hersey and Moore, 1949; Moore, 1950), physiology (Kampa and Boden, 1954*a;* 1954*b*) and on fisheries biology (Richardson, 1952; Haffner, 1952). Not all of the physical characteristics of those invertebrate organisms which cause scattering are understood as yet (Smith, 1951, 1954), but the air bladder in certain fish is regarded as an excellent scatterer of sound (Marshall, 1951; Hersey and Backus, 1954). The principles emerging from investigations into these various aspects of the subject may be generally applicable, but such principles are only to be derived from specific, detailed observations from many different localities.

Scattering layer development may vary from one area to another. Some of the variation is attributable to the distributions of the different organisms which are able to effect the scattering. Moore (1950) has discussed such variations in scattering in relation to the distributions of several species of euphausiids in the north Atlantic. On the other hand, strong development of layers could result from those high concentrations of animals which may be associated with areas in which intermixing of contiguous bodies of water of differing properties is taking place. Thus localised scattering might well occur in the upwelling waters believed to be present at several localities about New Zealand (Garner, 1953). On a larger scale, scattering could be associated with the —possible—extensive disruption of the water layering and the resultant mixing of the waters where north-south moving masses cross the Chatham Rise (Fig. 1). This topographic barrier to unrestricted flow rises from about 2800 m. to within 450 m. of the surface and lies



athwart the direction of movement of the water masses. Relevant to these points, it is of interest to note that the present examples of scattering are predominantly from two areas where mixed waters are believed to be present. One of these is to eastward of South Island, and is associated with the supposed area of disturbed water from the Chatham Rise obstruction. Moreover, the subtropical convergence migrates seasonally across this area, although its relationship to present examples of scattering is not known. The second area, in the south west of South Island, is believed to be associated with mixing between waters of subantarctic and subtropical origins (Deacon, 1937).

The records presented from New Zealand waters appear to be similar in essentials to those made elsewhere. Their chief value lies in showing that development of scattering is fairly widespread in the area. Two features are noteworthy. Several records have illustrated the successive descents from the surface of two or more separate layers, and conversely, the ascents up to the surface of distinct layers. Development of multiple layering during the descent or ascent of a layer has frequently been recorded, but the writer is unaware of any published records in which such a separation into layers persists up to the surface, or develops at the surface prior to the descent of the organisms.

The second feature is illustrated in Figure 8. It is a matter for frequent conjecture whether scattering is caused by planktonic animals, notably euphausiids (Boden, 1950; Moore, 1950), or whether it is caused by predatory fish accompanying and feeding on planktonic organisms which are undergoing vertical migration (Hersey & Moore, 1949). In Figure 8, the large, dense masses of scattering have the appearance of fish shoals. Also, the distinct layers, present in the left-hand mass, are strongly suggestive of scatter-

FIG. 9. Probable fish record made earlier in the day than that in Figure 8; "Discovery II" record, D3.

ing of planktonic origin. If the two types of scattering have been caused by fish and plankton as is suggested, this is a record of fish which are associated with ascending planktonic concentrations.

REFERENCES

Bary, B. M. In press. Species of zooplankton as a means of identifying different surface waters and demonstrating their movements and mixing. *Pacific Sci.*

Boden, B. P. 1950. Plankton organisms in the Deep Scattering Layer. *U. S. Navy Electronics Lab., Rpt. 186.* Pp. 29. San Diego, California.

Deacon, G. E. R. 1937. The hydrology of the Southern Ocean. *Discovery Rpt.* 15: 1–124. Discovery Committee, London. Cambridge University Press, London.

Garner, D. M. 1953. Physical characteristics of inshore surface waters between Cook Strait and Banks Peninsula, New Zealand. *New Zeal. Jour. Sci. and Technol. Sect. B.* 35(3): 239–246.

Dietz, R. S. 1948. Deep Scattering Layer in the Pacific and Antarctic Oceans. *Jour. Mar. Res.* 7(3): 430–442.

Haffner, R. E. 1952. Zoogeography of the bathypelagic fish *Chauliodus*. *System. Zool.* 1(3): 113–133.

Hersey, J. B., and R. H. Bachus. 1954. New evidence that migrating gas bubbles, probably the swim bladders of fish, are largely responsible for scattering layers on the continental rise south of New England. *Deep-Sea Res.* 1(3): 190–191.

Hersey, J. B., and H. B. Moore. 1949. Progress report on scattering layer observations in the Atlantic Ocean. *Amer. Geophys. Un., Trans.* 29(3): 341–354.

Johnson, M. W. 1948. Sound as a tool in marine ecology, from data on biological noises and the Deep Scattering Layer. *Jour. Mar. Res.* 7(3): 443–458.

Kampa, E. M., and B. P. Boden. 1954*a*. Submarine illumination and the twilight movements of a sonic scattering layer. *Nature Mag.* 174(4436): 869.

——— and ——— 1954*b*. Sonic scattering layer studies. *U. S. Off. Nav. Res.* NR 165–195, Rpt. 1.

Marshall, N. B. 1951. Bathypelagic fish as sound scatterers in the ocean. *Jour. Mar. Res.* 10(1): 1–17.

Moore, H. B. 1950. The relation between the scattering layer and the Euphausiacea. *Biol. Bul.* 99(2): 181–212.

Richardson, I. D. 1952. Some reactions of pelagic fish to light as recorded by echo sounding. [*Gt. Brit.*] *Min. Agr. and Fisheries, Fish Invest., Ser. II* 18(1): 1–20.

Smith, P. F. 1951. "Measurements of the sound scattering properties of several forms of marine life." Ref. no. 51–68 (unpublished ms.). *Woods Hole Oceanographic Institute.*

——— 1954. "Further measurements of the sound scattering properties of several forms of marine life." Ref. no. 54–16 (unpublished ms.). *Woods Hole Oceanographic Institute.*